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Recent Trends In Technological Innovation Research: A Bibliometric Analysis

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ABSTRACT

The research on technological innovation is an emerging trend. By utilizing bibliometric analysis this study investigates the researchers' specific interests towards technological innovation research and forecasts future advancements. The study comprehends the expansion of technological innovation literature year-wise and delves deeper to find the top contributors, institutions, subject area and the journals in this field. The data were obtained from the database like Scopus for the period of 2008-2022. On the selected collection of 6976 and 500 no. of articles the analyses were performed in two stages by utilizing Microsoft Excel and VOSviewer software respectively .It has been explored that the author with greatest contribution to the study of technological innovation is Truffer B and 'Sustainability of Switzerland' is the highest contributing journal. The 'Utrecht University' of Netherlands as the most contributing institution and Social Science as the most contributing subject area is borne out in this particular analysis. Furthermore, a co-occurrence of keywords was conducted to understand the recent trends and this analysis yielded four clusters, namely, 'environment and technological innovation system', 'energy efficiency and product innovation', Climate change & environmental regulation', 'absorptive capacity and sustainability' which are the expanding themes in technological innovation research for the years ahead.

Keywords: Technological Innovation, Innovation management, Bibliometric Review, Scopus database.

1. INTRODUCTION

Technological change is one of the most necessary phenomena for our economy and society. New technology contributes to the growth of the economy by enhancing the productivity of existing companies and by creating new job opportunities for the youth. As far as societal contribution is concerned, technological changes can help people to live a better life by improving healthcare systems, transportation and communication and by a host of other ways (Hannay, 1980). Innovation is a process where new ideas are generated, developed, nurtured and made useful. Therefore, Technological innovation can be explained as the process of innovation that focuses on technological characteristics of a product or a process (Mothe & Thi, 2012).Though, in the service sector this demarcation is non-existent and less meaningful as the product and process innovations mean the same(Mansury & Love, 2008; Mothe & Thi, 2012). Technological innovations are the result of the

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process of problem solving in a particular field of study or technological field to accomplish the sustained goals (Coccia, 2021).Technical proficiency and the technique for problem solving are essential components for technological innovations to be happened as they transform organizational and environmental inputs to new products or processes for meeting the needs of people and organizations, resolving their issues and supporting the specific objectives of adopters in the society (Coccia, 2021). The adoption of environment friendly technology has been emphasized since the last industrial revolution (industry 4.0) and the current researches on technological innovation intends to explore technological innovation as one of the important aspects of green transformation of our planet (Wang et al., 2021). This is the reason that the research on technological innovation is an emerging trend. Increasing numbers of publications in this field have been initiated which are obtainable to assess the characteristics of technological innovation and to delineate an intellectual framework out of it.

Bibliometric research provides a systematic perspective of information as the application of statistical methodology helps in identifying the emerging areas of research as well as provides a comprehensive overview of the literature by topics of interest (Vergara et al.,2021; Dzikowski, 2018). It is a great technique to summarize the findings and to identify the areas in which the study has been performed. This is also an effective method for developing conceptual models and theoretical frameworks (Snyder, 2019). Therefore, understanding the research trends of technological innovation have been made easier with the help of a bibliometric study. This method enables the presentation of intriguing findings to both individuals with and without prior knowledge of a subject (Casado-Belmonte et al., 2020).Though, there are some recent bibliometric studies on the domain of technological innovation found, such as, 'the relationship between green technology innovation and corporate financial performance'(Qing et al., 2022); 'technological innovation in food industry'(Castillo-Vergara et al., 2021); 'Technological Innovation Research in China and India'(Chatterjee & Sahasranamam, 2018);'A bibliometric method for measuring the degree of technological innovation'(Yeo et al., 2015); 'Technological innovation research in the last six decades'(Akbari et al., 2021), a very limited number of researches, as we understand, has been done to estimate the essential foundation of technological innovation research which is comprehensive and non- specific. Therefore, to fill the gap, this paper aims to analyse the scope of technological innovation research for the span of fifteen years i.e. 2008 to 2022 by presenting bibliometric review of the documents published in Scopus Database using Microsoft Excel and VOSviewer software. This study is among the very few ones that have used bibliometric research procedure to thoroughly examine technological innovation research progress and its logical underpinnings. Following are the research questions (RQ) attempted:

RQ1: What is the growth pattern of technological innovation research in the years from 2008- 2022?
RQ2: Who is the most contributing author?
RQ3. What are the most contributing journals?
RQ4. What are the most contributing institutions?
RQ5. Which is the most contributing subject area?
RQ6. What are the Keywords related to technological innovations?
RQ7. What will be the future trends in technological innovation research?

2. REVIEW OF LITERATURE

The most comprehensive work found so far on the technological innovation research is of Akbari et al.,(2021), published in the 'European Journal of Innovation Management'. It focuses on 1361 documents between the years 1961 to 2019 collected from Web of Science (WoS) database's Core Collection. Maximum of the study's co- citation of cited references reveals that there are two clusters that grouped all the articles. Articles on sources of innovation are organized in the first cluster, and articles about the technological innovation system are grouped in the second. The analysis of co-occurrence keywords reveals six clusters, namely, 'sources of innovation', 'environmental innovation', 'technological innovation system', 'economic growth', 'investment', 'R&D'. The findings also bring forth an interesting change of keywords. Some keywords are disappeared during the years 2000-2019 which were present in 1962- 1999. It indicates the changing trends- from the literatures on technological innovation and its determinants and performances to Research and development. Through the analysis of themes it has been found that Technological innovation management, models and the impacts have received more attention from researchers in recent years. Budianto et al., (2022) examined 408 documents that he published in the 'Journal of Sustainable Tourism and

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Entrepreneurship'. The study includes the documents on 'technological innovation in small and medium enterprises' available in Scopus Database from the year 1990 to 2023. It shows, the publication in this area, though fluctuated, had a tendency to increase. 'IEEE Transactions on Engineering and Management' with 36 no. of publications was the most contributing journal in this field. 'Technological Forecasting and Social Change' with 12 publications came in second and 'Technovation' stood third with 10 publications. The most prolific writer was Bala Subrahmaya who authored 7 books on the same subject. Next, Radicic with five articles was followed by Hervas-Oliver, Ferreira FAF, Zhang Y and Ferreira JJM with four articles authored by each. Among the countries, China brought out 50 documents and United Kingdom, produced 20 documents in this field. The United States and Singapore were enlisted after the United Kingdom as the most cited country in the same field. Vergara et al., (2021) in their study reviewed 1015 papers and it has been found that most of the documents (70% approx.) related to this subject area were published after 2010. The country which contributed highest number of studies (155 documents) is USA, followed by Italy and China with 12% and 11 % respectively. Among 3,112 authors, Wim Verbeke has the highest number of papers like 13 nos. and Sam Saguy has eight and Xavier Gellynck is with seven papers. 'The British Food Journal' with 104 papers is the top contributing journal in this field, next in line is 'Agro food Industry Hi-Tech' (94 papers) and then 'Food Policy' (67 papers). The co-occurrence analysis of keywords produced three important themes like 'attitudes',' impacts' and 'strategy'. 'Attitude' is the first motor theme which emphasizes the notion that consumer preferences are important to stimulate the new product development. The second theme is 'impact' which is connected with the technical aspects of food industry such as biomass, fat, bio composites etc. that influence the market or economy. The third driving force is 'strategy', number of studies deal with strategy focused on the factors that influence the success of incorporating innovation in the industry. Qing et al., (2022) conducted the same analysis to investigate the research publishing patterns that revealed a connection between green technological innovations and financial performances in corporate sectors. The study was conducted through Cite Space software, based on 251 articles from Web of Science (WoS). It was found the literature in this field was first published in 2007. Since 2015 it was a surge in the publications and 54 papers were published in 2021 alone. The most productive author in this area is Yaw Agyabengmensah (6 articles) followed by Ebenezer Afum (5 articles). In China the highest number of research has been done on this area, followed by Spain, Pakistan, and England. Among the institutional contribution, 'Dalian Maritime University' contributed the highest followed by 'Hong Kong Polytechnic University', and 'Sichuan University'. The 'Journal of Cleaner Production' was the most effective journal with 40% of the total contribution followed by 'Organization & Environment' contributes 20%. From the co-occurrence of keywords analysis we have found that, the keyword 'technology' is the oldest and long lasting and keywords like 'product innovation' and 'green innovation' are the newest destinations for the researchers.

3. METHODOLOGY

The primary task of bibliometric research analysis is finding the appropriate database which will be a perfect fit for the research (Akbari et al., 2021; Albort-Morant & Ribeiro-Soriano, 2016). In this research, the data were collected from Scopus database. Because of bibliographic extraction database needs to be of high quality and reliable (Herrera-Franco et al., 2020). Scopus and not Web of Science was chosen mainly for its broad coverage of multidisciplinary journals ranging from life science, physical Science, health science and social science and it is the largest abstract and citation database (Sinha & Nag, 2023). Despite having more collections, Google Scholar was not selected because of its inadequate indexing standards and difficulties in retrieving bibliographic information (Moosa & Shareefa, 2020). Thus, Scopus was found more appropriate for this bibliometric research. There are software like Gephi, Leximancer, VOSviewer are used to analyse the bibliometric data in a very realistic way (Donthu et al., 2021). In this paper we have used VOSviewer which was developed by Van Eck & Waltman for constructing and viewing bibliometric maps (Van Eck & Waltman, 2010). The methodology as used by Choudhury & Routray (Choudhury & Routray, 2024) was applied to accomplish this study's objectives.

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3.1 Stage I: Data Source and Retrieval Search Strategy

Data extraction started from the Scopus database by using the keyword 'technological innovation' OR 'TI'. Several publications contain every TI component within the allotted time span were identified. With the search parameters restricted to the keywords, abstract and title, 30,523 publications were found. The authors then narrowed the research by using the 'inclusion and exclusion criteria' as mentioned below.

3.2 Stage II: Search and documents selection

In this stage, the authors kept the search process rational and purposeful by choosing the publication years from 2008 to 2022 (15 years) and the number of research articles was reduced to 23,850. Further, the search process was narrowed down to 7396 papers by selecting publications from specific areas like Social Science and Business Management and Accounting. Then it was found that 717 papers among them were not in English. So, excluding the non-English papers, the number reached 6982.

3.3 Stage III: Data extraction and cleaning

The researchers found some extra rows that had been added but not part of the selection process and ran a check for some duplicate records; some blank cells were also detected. So, after obtaining the data set, they had to clean the data in Ms. Excel and 6 records were removed. Finally the data were examined and validated in light of their relevance to this study's subject and substance. As a result 6976 articles were taken for phase I analysis and the first 500 most cited documents' bibliographic information were chosen for phase II analysis. These two sets of data were exported in comma-separated values (CSV) format, including bibliographical data, citation data, abstract, keywords, funding information and references.

3.4 Stage IV: Data analysis and visual representation

Two phases of data analysis were carried out for this study. In the first phase, 6976 articles were analyzed using the Scopus database to determine the annual increase of publications of research as well as the research contributions made by the first 10 authors, 10 institutions, 5 journals from the top of the list and most contributing subject area. In the second phase, the VOSviewer software (version 1.6.18) was used to analyze the author keywords based on the keyword clusters. The flow diagram of research methodology used in this particular study is shown in figure 1.

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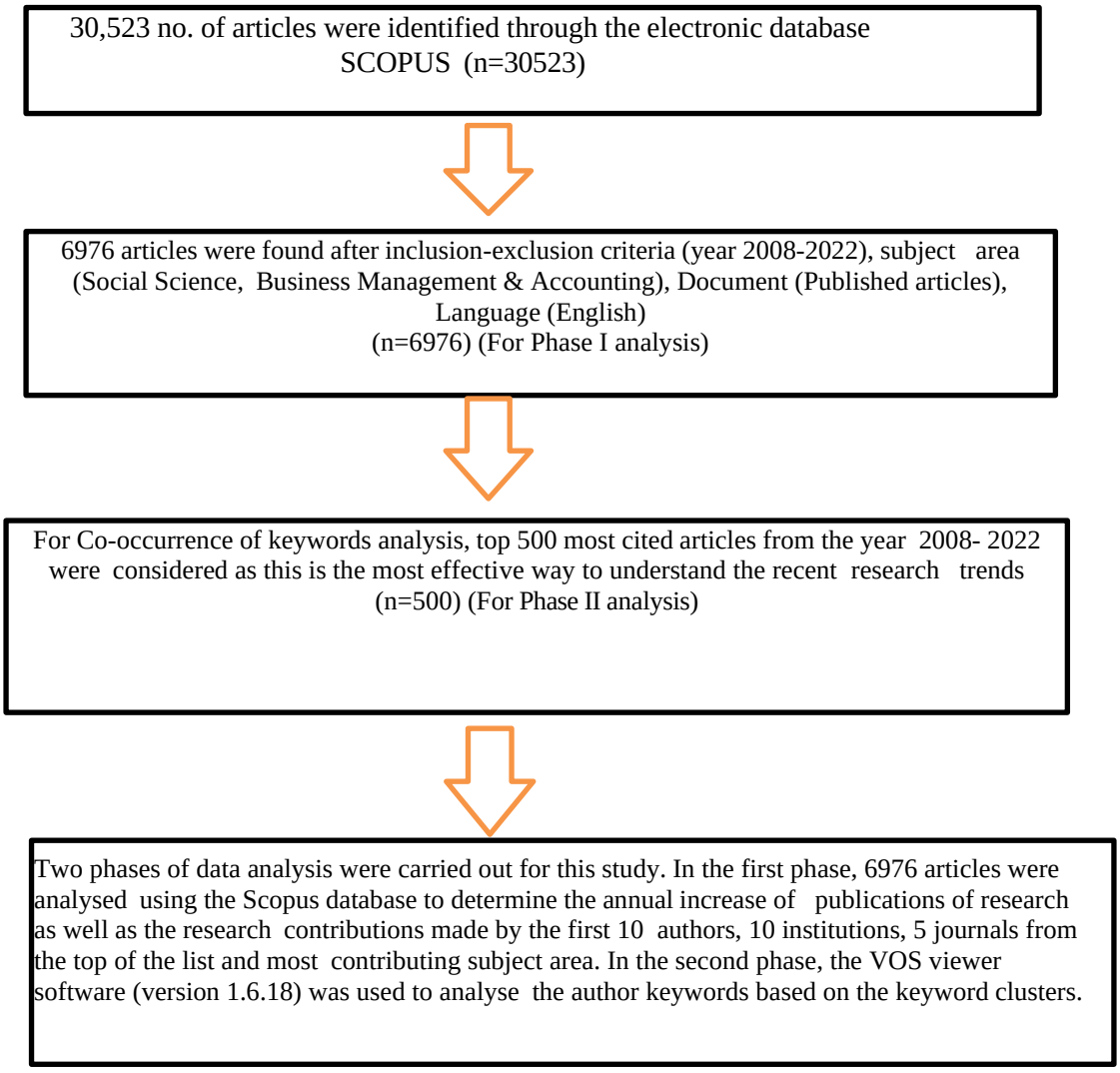

Figure 1. Flow chart of data selection process
Source: Authors

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4. ANALYSIS

4.1 Technological Innovation Research status (Phase-I)

4.1.1 Year Wise Growth of Publication

Figure 2 demonstrates the growth of research articles related to Technological Innovation from the year 2008 to 2022 (15 years). The graph depicts the year wise growth of publication. This growth is not consistent but rather arbitrary in different levels. Since 2017, technological innovation researches started moving upward. From the year 2017 to 2018 the growth is 27.7%. But in 2019 the growth rate reduces to 15.6% which again rises steadily in 2020 and 2021 by 18.6% and 23.7% respectively. 1324 no. of research studies were published in the year 2022. The growth rate is also highest in last 15 years i.e. 31.7% in between 2021 and 2022. The graph's downward trajectory might have been influenced by the saturation concerning development of new technologies towards the end of 2018 (Jemala, 2021); the emergence of open innovation and the growing culture of knowledge distribution and sharing during the COVID 19 pandemic years expanded the scope of research might be the reason of highest growth rate in the years 2021 and 2022 (Serbulova et al., 2020).

Figure 2: Documents Analyses by Year
Source: https://www.scopus.com

4.1.2 Top Contributing Authors

During the period 2008 to 2022, Truffer, B. of University of Utrecht, Netherlands has contributed the highest number of articles (21) followed by Coccia, M. (20) of National Research Council of Italy and Hekkert, M.P. of Copernicus Institute of Sustainable Development, Netherlands. Figure 3 and Table 1 display the top ten authors and their total number of contributions. Table 1 reflects the most impactful article and its author in this field. First five top contributing authors and their articles with highest citations have taken into consideration. Markard J. and Ratten, V. have same no. of articles on technological innovation and both are the first authors of their highest cited articles but Markard J received 734 citations which is much higher than his fellow author. It is the same article co-authored by Truffer, B who is the highest contributing author in this field. Therefore, Markard J, as enlisted among the first five most contributing authors and being the 1st author of 2nd highest cited article on technological innovation research can be considered the most influential author in this field.

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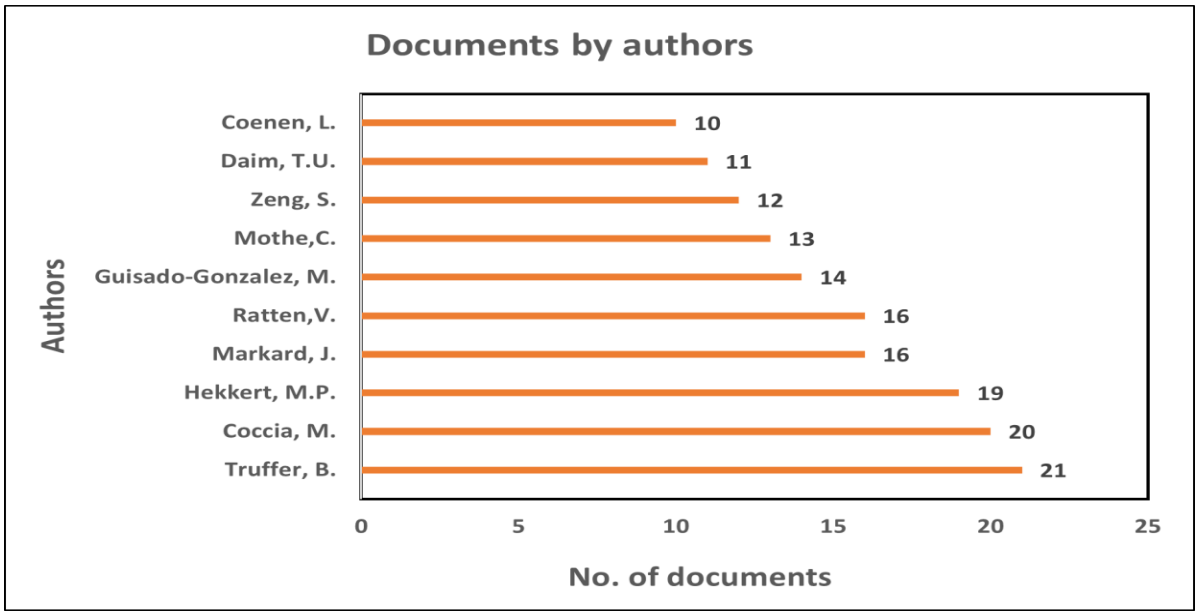

Figure 3: Documents Analyses by author
Source: https://www.scopus.com

Table 1: The articles with highest citations by top 5 authors

S.no	Author name	Total no. of Publication	Most cited article	Highest citation received	1st author/ Co-author
1.	Truffer B.	21	Markard, J., & Truffer, B. (2008)	734	Co-author
2.	Coccia, M.	20	Coccia, M. (2017).	130	1st author
3.	Hekkert, M.P.	19	Wieczorek, A. J., & Hekkert, M. P. (2012).	301	Co-author
4.	Markard, J.	16	Markard, J., & Truffer, B. (2008).	734	1st authors
5.	Ratten,V.	16	Ratten, V. (2014).	102	1st authors

Source: Authors

4.1.3 Highly Contributing Journals

Table 2 displays the presentation of the various sources with year wise publication of the documents in number in descending order. Our Database indicates a list of top 5 journals which published articles based on Technological innovation in the last 15 years .The journal of 'Sustainability' (Switzerland) contains 498; 'IEEE Transactions on Engineering Management journal' contributed 283 articles; 'Journal of Cleaner Production' has 248 articles. The journal, 'Technological Forecasting and Social Change', though, has contributed 245 articles in this field but the article with highest citation (495 citations) belongs to this journal. Our further research revealed, there are 46 articles from the journal of 'Technological Forecasting and Social Change' are enlisted among the first

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500 most cited articles on Technological innovation field indicates, this journal has the most impactful contribution to the Technological Innovation research from the year 2008 to 2022.

Table 2: Top 5 journals contributing to technological innovation

Journal	Total no. of Publications	Publisher	Country	Most cited article	Highest citation Received
.'Sustainability' (Switzerland)	498	MDPI	Switzerland	Guo, Y., Xia, X., Zhang, S., & Zhang, D. (2018).	169
'IEEE Transactions on Engineering Management'	283	IEEE	United States	Chu, Z., Xu, J., Lai, F., & Collins, B. J. (2018).	83
'Journal of Cleaner Production'	248	Elsevier	United Kingdom	Liu, X., & Bae, J. (2018).	290
'Technological Forecasting and Social Change'	245	Elsevier	United States	Wang, Y. M., Wang, Y. S., & Yang, Y.F. (2010)	495
'Technology Analysis And Strategic Management'	96	Routledge	United Kingdom	Bergek, A., Jacobsson, S., & Sandén, B. A. (2013)	244

Source: Authors

4.1.4. Highly Contributing Institutions

Table 3 demonstrates the number of studies in total and their contribution in percentage of the first 10 organizations in Technological Innovation research respectively. Unsurprisingly, the Universiteit Utrecht or Utrecht University is found as the leading institution by producing 77 papers which are 16 % of the total contributions made by the 10 leading institutions just as it is already identified that Truffer, B. who has contributed the highest number of articles (21) belongs to the same university. The Tsinghua University of China and the Universidade de Sao Paulo of Brazil have produced 59 (12 %) and 58 (11 %) papers and secured 2nd and 3rd positions respectively. These top 10 institutes are responsible for almost 7% of the total contributions on technological innovation research within the period 2008-2022

Table 3: Top 10 institutions contributing to technological innovation

S.no	Institution	Country	Total no. of Publication	% contribution
1.	Universiteit Utrecht	Netherlands	77	15.21%
2	Tsinghua University	China	59	11.60%
3.	Universidade de Sao Paulo	Brazil	58	11.46%
4.	Chinese Academy of Sciences	China	54	10.67%
5.	Beijing Institute of Technology	China	47	9.28%

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6. politecnico di Milano	Italy	47	9.28%
7. Xi'an Jiaotong University	China	43	8.49%
8. Copernicus Institute of Sustainable Development	Netherlands	42	8.30%
9. Wageningen University & Research	Netherlands	40	7.90%
10. The University of Manchester	United Kingdom	39	7.70%
Total		506	100%

Source: Authors

4.1.5 Highly Contributing Subject Area

The analysis shows (Figure 4) that maximum papers have come from Social Science Area (25.9%). AS technological innovation is a major engine for human well-being and economic activity, this is no wonder that maximum papers will be coming from Social Science area that covers the different societal functions such as governments, organization, economic growth and human behaviour. 23.2% of the documents are from Business Management area and 9.9 % has covered Engineering domain.

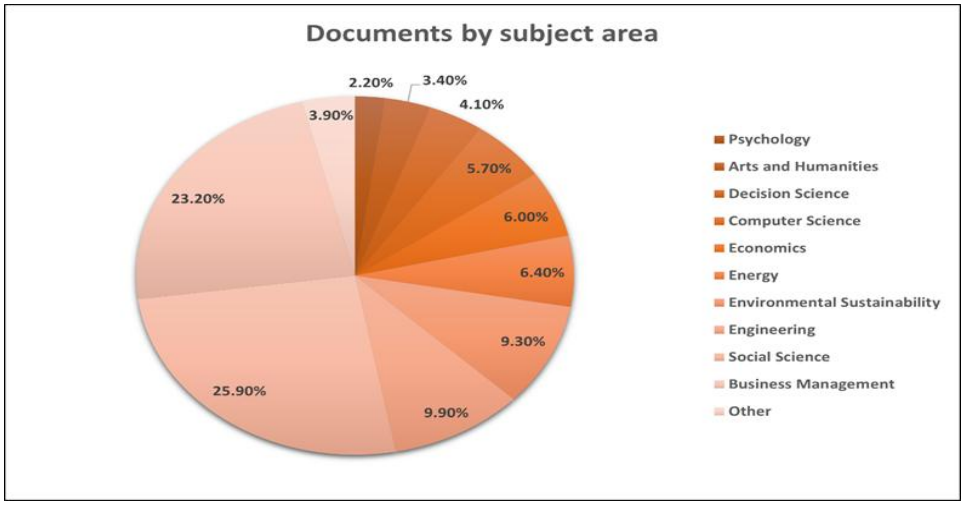

Figure 4: Documents Analyses by Subject Area
Source: https://www.scopus.com

4.2 Bibliometric Analysis:

4.2.1 Co-occurrence analysis of Keywords (Phase-II)

The section has illustrated the core structure of keyword co-occurrences from 500 documents on technological innovation from the year 2008 to 2022. A total of 1723 author keywords are taken and a minimum of 8 occurrences of a keyword have been recognized as a threshold and 18 keywords met the criterion which is demonstrated in Figure 5 and Table 4. These 18 keywords are grouped in 4 clusters (each represented by a distinct colour). The circles in various colours termed as nodes. Each and every node is interconnected through lines representing their frequency of association with one another. The thickness of this line represents the low or high frequency of association between the nodes. The distance of the nodes from one to another constitutes the frequency of co-occurrence between the items. 'Technological Innovation' as a keyword occurs 93

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times and linked with 13 other keywords directly. The maximum number of occurrences of 'Technological innovation' is found with the keyword 'innovation'.

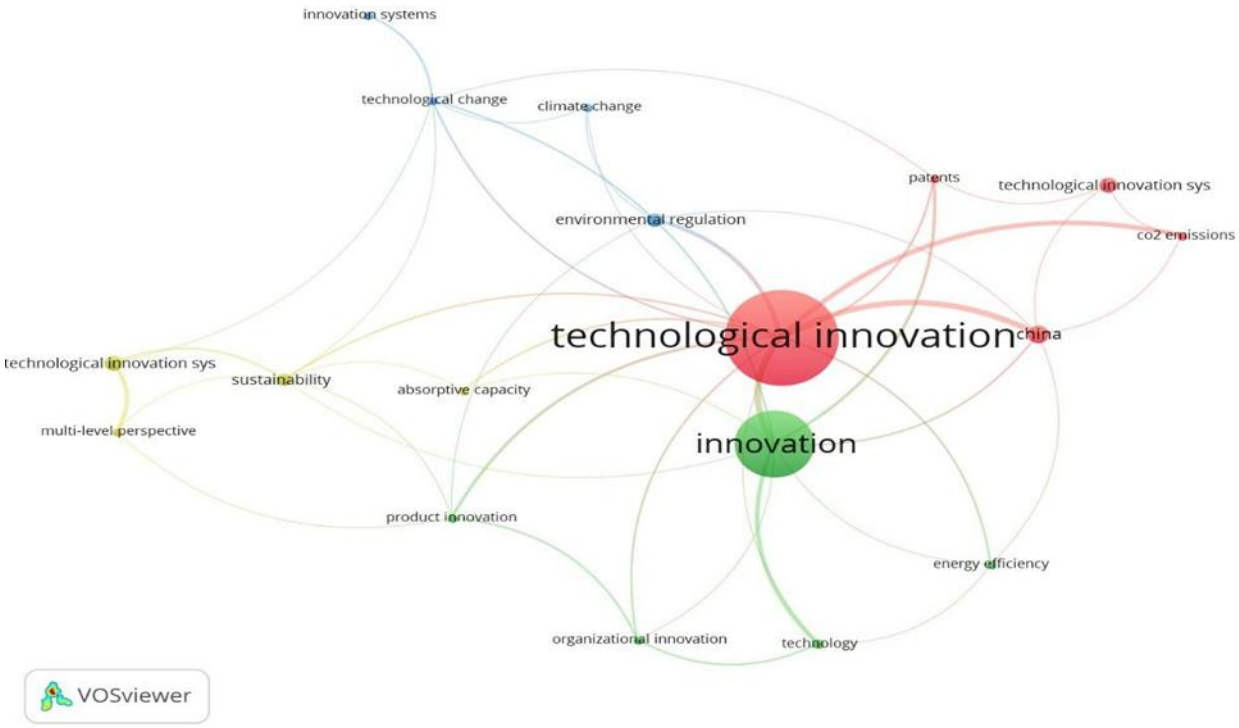

Figure 5: Co-occurrence analysis of cited keywords
Source: Analyzed by authors

4.2.2 Thematic evaluation of Keyword Clusters

Cluster 1: Environment and technological innovation system

This cluster focuses on green technology to reduce CO2 emissions, technological innovation, and the technological innovation system. For an organization to gather external knowledge effectively, it must build upon its existing knowledge in the same area. Besides knowledge storage, the distribution of knowledge and expertise within the organization is crucial. This is the essence of the technological innovation system: understanding current knowledge and making it market-viable (Bergek et al., 2008). Innovation needs to grow, develop, and be utilized for the benefit of society. Liu & Bae (2018) suggested, improving energy efficiency can be accomplished through technological innovation and maximizing the consumption of renewable energy. Green technology innovation can mitigate CO2 emissions through industrial structure upgrading (Lin & Ma, 2022). Additionally, Chen & Lee (2020) highlighted that promoting green technology innovation allows technologically advanced nations with high CO2 emissions to lower emissions in surrounding nations. Planko et al., (2016) described how networks of actors collaborate to foster an atmosphere conducive to innovative sustainability technologies. A strategy framework was developed through a Dutch smart grid case study highlights four key areas—socio-cultural changes, technology development, market creation and coordination, each involving specific system-building activities. The information borne out of this cluster indicate the scope of future studies on the transition process of technological innovation system while giving more emphasis on spatial contexts which can be helpful for the policymakers in industry transformation and urban planning.

Cluster 2: Energy efficiency and Product Innovation

This cluster examines the function of technology in driving innovation and its influence on the probability of product innovation; alongside other innovation activities it aims at achieving energy

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efficiency within organizations. According to Anzola-Román et al., (2018) internal R&D initiatives and externally sourced innovation approaches, both have positive influences on organizational innovation. Subsequently, this organizational innovation brings about a favourable impact on technological innovation, specifically in the domain of product innovation. Today, product innovation is among the various strategies that enable nations to achieve energy efficiency(Chen et al., 2021). Dudin et al., (2019) proposed that the energy sector should allocate investments toward the development and implementation of technologically advanced solutions. This strategic investment is imperative to satisfy the escalating demand for energy and to construct a robust infrastructure for renewable energy resources. Market attention, efficiency, and green innovation are identified as key drivers of product innovation. When considered together, energy efficiency plays a moderating role in the influence of market attention on new product development. This cluster particularly emphasizes on balancing product innovation with energy efficiency which is challenging, as prioritizing one can unintentionally impact the other (Gerstlberger et al., 2014). Therefore, aligning three different strings i.e. green business model, green product innovation and innovations that is environment friendly and energy efficient is important and needs to be developed in both, theory and practice.

Cluster 3: Climate change and Environmental Regulation

This cluster examines climate-sensitive technology. Chhetri et al., (2012) demonstrates that conventional technological innovation becomes more efficient when supported by resource endowment and external tacit knowledge, enhancing its responsiveness to climate change. Thus, recent innovations should align with global environmental efforts, though research suggests that stringent regulations can hinder original innovation within organizations. Governments must support businesses in adapting to shifting market conditions and implementing innovative technologies, while citizens and the government can collaborate to reduce pollution and improve green productivity (Li & Wu, 2017). Polonsky et al., (2011) identified four key issues for climate change regulation and paved the way for future research direction: whether carbon emission management will be global or regional ("scope"), who bears the costs ("who pays"), whether the system will be market- or compliance-based ("mechanism"), and what constitutes a credible carbon offset ("criteria"). For example, China's gradual green transformation has reduced pollution, though progress varies regionally. Paradoxically, weak regulations lower carbon intensity, while overly stringent regulations can undermine green industrial transformations (Hou et al., 2018).

Cluster 4: Absorptive Capacity and Sustainability

Technological innovation often requires businesses to redesign their models by integrating both internal and external knowledge, with the ability to absorb external knowledge being crucial for long-term change. Absorptive capacity as an Intermediary actor helps to accelerate the shift toward more sustainable socio-technical systems (Kivimaa et al., 2019).This transition can be understood through a multi-level perspective: the micro level (niche) for radical innovations, the meso level for incremental improvements, and the macro level (landscape) for the broader context (Walrave & Raven, 2016). Effective transition involves both the growth of disruptive innovations and the creation of policies that drive major changes in socio-technical systems. Energy policies should encourage the adoption of energy-efficient technologies to promote environmental sustainability. Additionally, firms should seek and utilize external information alongside their existing resources to foster economic, social, and environmental sustainability (Kirikkaleli & Adebayo, 2021). Therefore, absorptive capacity plays crucial role in learning and firm performance. Joss (2011) brought the concept of ‘eco-city’ which can be considered as a hub or laboratory where new technology and innovation related knowledge will be tested, developed, nurtured and diffused. Therefore, this cluster contributes to the convergence of technological innovation management with absorptive capacity, sustainable living and urban development within a democratic governance framework.

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Table 4: keyword clustering

Cluster	Keywords and Themes	Research Papers
Cluster I	**Topic: Environment & Technological Innovation System** 5 items: China, Co2 emissions, patents, technological innovation, technological innovation systems	Bergek et al., 2008 Coenen et al.,2012 Liu & Bae, 2018 Planko et al, 2016 Lin & Ma, 2020 Chen & Lee, 2020 Adebayo & Kirikkaleli, 2021 Tsai, 2009 Camisón & Villar-López, 2014 Gerstlberger et al., 2014 Pan et al.,2019 Anzola-Román et al.,2018 Chen et al., 2021
Cluster II	**Topic: Energy efficiency and Product Innovation** 5 items: energy efficiency, innovation, organizational innovation. product innovation, technology	Dudin et al., 2019 Guo et al.,2018 Markard & Truffer, 2008 Banister,2011 Chhetri et al., 2012 Li & Wu , 2017 Petralia et al., 2017 Polonsky et al. 2011 Hou et al., 2018
Cluster III	**Topic: Climate change and Environmental Regulation** 4 items: Climate change, environmental regulation, innovation systems, technological change	Joss,2011 Martín-de Castro, 2015 Dóci et al., 2015 Kivima et al., 2019 Begnini et al., 2022 Kirikkaleli, Adebayo., 2021 Ashford & Hall 2011
Cluster IV	**Topic: Absorptive Capacity and Sustainability** 4 items: absorptive capacity, multi-level perspective, sustainability, technological innovation systems	

Source: Authors

5. CONCLUSION

Research on technological innovation will become more sophisticated and well organized as seen by the growing number of research publications in this field and the researchers' increasing interests in this area. The main objective of Bibliometric survey on Technological Innovation is to put forward the prevalent research, summarizing them and investigating the substance of the articles for the future researchers of the same area. The entire research work in this paper was executed by considering the 'Scopus' which is the largest and most effective database in use globally. The database has been taken into account from the year 2008 to 2022. It has been found that the growth pattern of technological innovation research is not linear and always not consistent. Even so, with the advancement of years, the gap between existing and the newly added literature has been increased. For example, in the year 2019 to 2020, 129 literatures were added. Next, in between 2020 to 2021, 204 literatures were added. From 2021 to 2022, 363 literatures have been added to the database. Though, Truffer B. was found as the most contributing author in this field, Markard J. has been proven the most influential author in this field. The journal of 'Sustainability' (Switzerland) contributed the highest no. of articles in this field but 'Technological Forecasting and Social Change' is the journal which has produced some of the most impactful articles on the Technological Innovation from the year 2008 to 2022. The Utrecht University is found as the leading institution in publishing

the research articles on technological innovation while most of the articles are produced from the subject area of social science.

To understand the trends in technological innovation research we conducted co-occurrences of keywords analysis taking 500 most cited papers from the Scopus database. In this analysis, out of 1723 author keywords 18 met the thresholds which are grouped in 4 clusters namely 'environment and technological innovation system', 'energy efficiency and product innovation', Climate change & environmental regulation', 'absorptive capacity and sustainability'. Quite same observations are found in the research of Akbari et al.,(2021) and Chatterjee & Sahasranamam, (2018), though the later have done their analysis on two Asian countries like India and China. In keyword analysis, the present study found 'technological innovation' is the most researched keywords followed by 'innovation' and country wise 'China' is most used keywords which imply the contribution of China in technological innovation research is undeniable. Therefore, based on the analysis, it may be summed up that 'environment and technological innovation system', 'energy efficiency and product innovation', Climate change & environmental regulation', 'absorptive capacity and sustainability' will be the expanding themes in technological innovation research for the years ahead.

As the literature are evaluated, this study tries to highlight some important areas which can be utilized by the researchers as well as the practitioners and opens new avenues for future research, which needs to address for filling the knowledge gap in the academic literature in this field (Tanwar & Verma, 2024). Summarizing the cluster wise discussions, we may state that more researches can be done on the transition process of technological innovation system with emphasis on spatial contexts; further researches need on technological innovations that are environment friendly and energy efficient; studies can be conducted on technological innovation management with absorptive capacity and sustainability; and further discussions necessitate on governmental policies pertaining to climate change and reducing carbon intensity . Another interesting aspect that draws this study's attention is diffusion of innovation. Invention, innovation and diffusion are the three stages of technological innovation (Akbari et al., 2021; Diaconu, 2011). In the 'invention' stage, R&D is the main focus. Different sources of innovation like absorptive capacity, energy efficiency and technological innovation systems are the players of second stage which are the main concerns for this study. The next one, 'diffusion' describes the relative speed with which people and organization adopt the new products or processes (Coccia, 2021). There is little or no literature found to highlight this stage. Therefore, it is recommended to conduct future studies on examining whether consumers are paying for the innovation or not.

The outcome of the present study will inspire the industry professionals too to create a knowledge based resources which is static, heterogeneous and to some extent ambiguous for the competitors to duplicate them. The managers will realize that they can engage in innovation process through the creation of innovation systems and their participation in innovation networks. By exploiting environmental opportunities they can achieve a competitive advantage too. Moreover, an appropriate system needs to be developed inside the organization to implement technological innovations including IPR, patents and other technology supports which are the necessities to increase the core capabilities of a company's R& D wings (Akbari et al., 2021).

This study has some limitations though, despite its best efforts to be thorough within the parameters of its scope. It has not incorporated data from other databases and restricted to Scopus only and considered the publications for 15 years only. So, some prospective papers might not have included which have earlier or most recently been published. Therefore, by collecting more documents from several other relevant data bases with a vast range of publications will broaden the scope of investigation based on the future directions and the list of relevant questions that the present study has explored.

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